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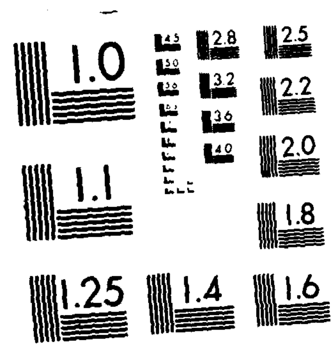
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FOREIGN TECHNOLOGY DIVISION

BEHAVIOR OF AN ARC IN A PLASMA CONTACT OF A HOMOPOLAR GENERATOR

by

I.S. Rogachev and L.I. Yantovskiy

EDITED TRANSLATION

FTD-ID(RS)T-0404-83 25 April 1983

MICROFICHE NR: FTD-83-C-000533

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English pages: 7

Source: Vestnik Khar'kovskogo Politekhnicheskogo Instituta, Nr. 29(77), Nr. 3, 1968, pp. 83-87

Country of origin: USSR
Translated by: Victor Mesenzeff
Requester: FTD/TQTD
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П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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BEHAVIOR OF AN ARC IN A PLASMA CONTACT OF A HOMOPOLAR GENERATOR

I. S. Rogachev and L. I. Yantovskiy.

The construction of electrodes, their cooling method, and service life, and also the electrical parameters of the contact, depend on the state and behavior of a plasma contact in a homopolar generator [1]. The literature is devoid of any data on the study of this problem. This article presents certain results obtained from an experimental study of the microscopic processes in a plasma contact.

Experimental Device

The experiments were conducted on a model of an evacuated homopolar engine with one plasma contact, described in [1]. The difference of the device consisted in the fact that its immobile electrode is in the form of a concentric ring cut into three equal segments I, II, and III, each with its own shunt (Fig. 1). The clearance between the adjacent segments was 1.5–2 mm. The annular segments were mounted on an insulating ring. The discharge gaps between the disk's periphery and the internal surface of each of the segments could be identical or different. The width of the working surface of the rotating and stationary electrodes was 14 and 10 mm, respectively. A transverse magnetic field was created in the discharge gap by the excitation coil's leakage flux. Ampere law was used to determine the direction of rotor's rotation for the known directions of the magnetic field and current. The oscillograms of currents I', I", and I"' flowing through the annular segments, registered by the vibrators, determined the location and direction in which the plasma arc moved. The rate at which the arc moved after the

direction of its motion had been stabilized was determined by the time it took the current to pass through a segment of known length. The current of the arc was varied by a ballast resistance, while the induction of the transverse field by the current of the excitation coil.

The Hall device was used to determine the values of indiction in the working and discharge gaps for different excitation currents. During testing, the pickup registered the induction in the gap and half-turns of the rotor simultaneously. For this the disk had two recesses, which were diametrically opposed. At the moment when a recess was in front of the pickup, it recorded the attenuation of induction. The rotor speed was determined by the frequency of the half-turn marks recorded by a vibrator. A mechanical closer - pickup - was used for visual observation of the disk's speed, and also for recording its speed in the absence of the magnetic field. It was in the form of an insulated washer with a conducting segment which was slipped over the rotor's shaft. The rotation of the disk across the conducting segment and an auxiliary brush created brief closings of the measurement circuit, which created square current and voltage pulses in it and which were fed to a vibrator and the input of an electronic frequency meter - ICh-7.

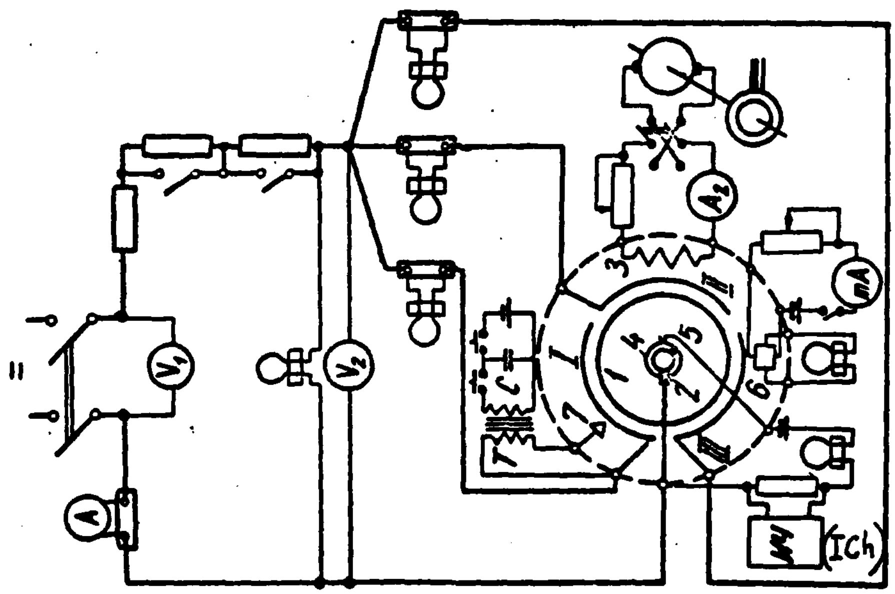

Fig. 1. Diagram of the device:

1 - rotor, 2 - central brush contact, 3 - excitation winding, 4 - washer-pickup of revolutions, 5 - brush of the pickup of revolutions, 6 - Hall device, 7 - igniting electrode of starter, I, II, III - annular segments of the stationary electrode; C - starter condenser; T - starter transformer; ICh - frequency meter.

In another version of the experimental device we used not a segmented but a whole annular electrode with one output. In this case the motion of the arc was registered using its luminous radiation by means of photodiodes arranged along the ring of the discharge gap. The amplified photodiode signals were recorded by the vibrators, and the speed of the arc was determined by the sequence order and pulse frequency of the diodes.

The temperature of the circular electrode was controlled by means of a chromel-copel thermocouple. The engine was activated by a pulse starter [2]. The boundaries of the experiments were defined by the following limits of variable values: arc current I=30–200 A, peripheral rotor speed v=0–150 m/s, pressure $p=1.5\cdot10^{-2}$ mm Hg and higher, magnetic induction of the transverse field in the discharge gap B_p=0–0.27 T, length of the discharge gap δ_p=0.2–1.2 mm, and temperature of the stationary electrode t^o=20–400^{o}C. The materials of the rotating and stationary electrodes were magnetic steel and copper, respectively.

<u>Results of the Experiments</u>

1. The arc is concentrated under any conditions, i.e., a discharge occurs only in one spot of the circular discharge gap at each moment. In the oscillograms shown in Figs. 2 and 3, at each moment, the current flows only through one annular segment, and the photodiode registers only the short light pulses (Fig. 4).

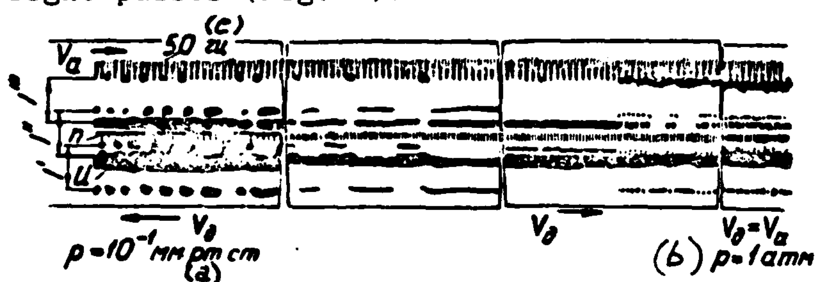

Fig. 2. An oscillogram segment showing the motion of the arc as pressure changes (rotor-anode).

KEY: (a) mm Hg (b) atm (c) Hz

2. In the discharge gap the arc has an ordered motion as a result of the effect of the transverse magnetic field and rotation of the rotor.

3. In the case of the segmented stationary electrode, the arc jumps to the next segment without extinguishing as it moves along and the

moment of the jump is accompanied by a brief rise in voltage.

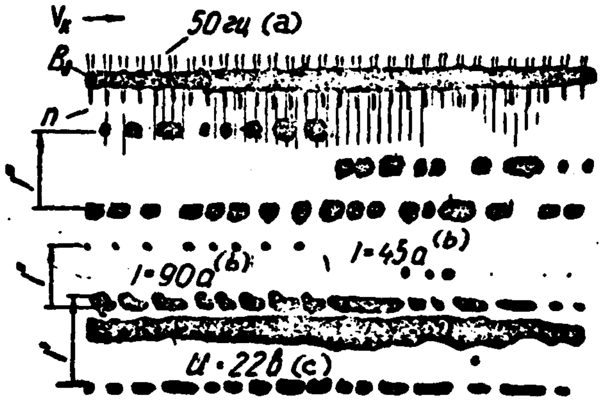

Fig. 3. An oscillogram segment showing the motion of the arc as the current and inverse polarity (rotor-cathode) change.

KEY: (a) Hz (b) A (c) V

4. The direction of the arc and its speed depend on the direction and magnitude of the magnetic field, polarity of the electrodes, direction and speed of the rotor, pressure, length of the discharge gap, and magnitude of the current.

5. At a low pressure of residual gases (approximately down to 1 mm Hg), the motion of the arc relative to the cathode, independently of its rotation, is in the direction that is opposite to the action of a pondermotive force, which is determined by the nature of motion of the cathode spot. This can be seen from the oscillograms in Figs. 2 and 3. When a cathode is stationary, the arc moves towards the rotating anode (first section of the oscillogram in Fig. 2). When the cathode rotates (Fig. 3), even though the arc does move in the direction of rotation of the rotor, however, it does so at a slower rate than the rotor. In both cases the speed of the rotor is identical. When the direction of the pondermotive force was changed by switching the direction of the magnetic field quickly while the rotor, braking, continued to rotate because of the stored kinetic energy, the direction of motion of the arc reversed and had a previous level rate of speed in the case of the stationary cathode. When the cathode rotated the direction of the arc did not vary and its speed became higher than that of the disk. The so-called reverse motion of the cathode spot observed here with both

stationary electrodes is known, however, the reasons for it have not been explained. The arc moved in the direction of the pondermotive force only during the initial seconds after the arc was excited, when the speed of the disk was low and it had a positive polarity; in this case the arc moved synchroniously with the rotor, not sliding over it. Then the direct motion was disrupted and, finally, the reverse direction of motion would stabilize firmly.

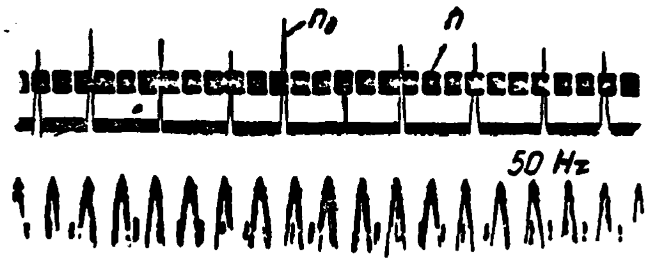

Fig. 4. An oscillogram segment taken with a solid circular electrode, when the motion of the arc was recorded by means of luminous radiation (n_{ϑ} - photodiode pulses, n - rotor rotation marks).

6. With the exception of the initial seconds, at low pressures the anode end of the arc is considerably more mobile relative to the anode than the cathode end relative to the cathode, independently of the polarity of the rotating and stationary electrodes, direction of rotation, and action of the ponderomotive force. Thus, the greatest value of the arc slide along the anode $s_{\text{а}}=v_{\text{а}}-v_{\text{д}}\approx 160$ m/s, where as along the cathode - $s_{\text{к}}=|v_{\text{к}}-v_{\text{д}}\approx 35$ m/s. Since the length of the arc is insignificant, we assume the linear velocity at all points of the arc to be identical.

Apparently, it is possible to obtain even greater slidings of the arc along the anode by using higher speeds of the disk. If we assume that the anode end has an absolute mobility along the anode, the speed of the arc in vacuum is determined only by the conditions of the cathode and $v_{\text{д}}=v_{\text{к}}+v_{\text{п}}$, where $v_{\text{д}}$ is the speed of the arc, $v_{\text{к}}$ - speed of the cathode, and $v_{\text{п}}$ - speed of the cathode spot relative to the cathode. A positive direction of speed can be assumed to be, for example, the clockwise direction. Then the sliding along the anode and cathode will be

$$s_{\text{а}} = |v_{\text{а}} - v_{\text{д}}| = |v_{\text{а}} - v_{\text{к}} - v_{\text{п}}|, \quad s_{\text{к}} = |v_{\text{к}} - v_{\text{д}}| = |v_{\text{п}}.$$

respectively.

7. The direction and magnitude of speed of the cathode spot $v_{\text{п}}$ have a strong dependence on pressure. As can be seen from the oscillograms in Fig. 2, where $v_{\text{д}} = v_{\text{п}}$, the motion of the cathode spot is reverse at low pressures, and, as the pressure increases, the rate of reverse motion decreases, stoppage occurs, and then the direction of motion changes. The motion of the cathode spot is straight at the atmospheric pressure. A detailed study was not conducted under these conditions due to an increase in the arc's voltage and increase in losses which heated the electrodes to a great extent.

8. There is less sliding along the cathode S_k, when the cathode is a rotating steel electrode rather than a copper cathode.

9. With a stationary cathode and rotating anode the motion rate of the arc is higher with a longer discharge gap. Thus, in the experiment (oscillogram in Fig. 2), the discharge gaps for the segments were determined to be different: for segments I and II - about 4 mm and for segment III - about 7 mm. As can be seen from the oscillogram, the speed of reverse motion of the cathode spot along the cathode $v_{\text{п}}$ (speed of the arc) in segment III could have been several times higher than in segments I and II. When the discharge gap was less than 0.2 mm, the movement of the cathode spot ceased. Erosion of the cathode increased with a decrease in the gap and rate of the cathode spot.

10. The cathode spot can have a directed motion along the cathode only in the presence of a certain transverse magnetic field. After the spot began to move, the increase in induction of the magnetic field had little effect on the rate $v_{\text{п}}$ within the bounds of the experiments. In the absence of a magnetic field the arc does not rotate if the cathode is stationary and rotates synchroniously with the rotor when the cathode rotates.

11. Within the limits of the experiments, the speed of the arc depends little on the force of the current (Fig. 3).

12. the Speed of the arc can vary with each new revolution of the arc. These variations were observed over a period of several tens of fractions of a second, when other conditions do not have the time to change significantly. Changes in speed are especially noticeable when the circular electrode has breaks, which can be explained by certain

delays of the arc on the trailing edges of the segments. This is supported also by the increased erosion of the trailing edges with their negative polarity. If the circular electrode is solid, the fluctuations in the speed of the arc diminish significantly (Fig. 4).

Conclusions

1. Forced displacement of the cathode and anode spots occurs in a plasma contact of a homopolar generator as a result of the rotation of the rotor and the effect of the leakage filed of the excitation coil.

2. Depending on the polarity of the field and pressure, the arc in contact can rotate both towards the action of the ponermotive force and in the opposite direction.

3. To reduce erosion of the electrodes, one should avoid the conditions when S_a and S_k can become equal to zero or very small, i.e., do not permit the worsening of vacuum, short length of the discharge gap, weak transverse field, and the rotor speed at which $v_a - v_k = v_n$.

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